

OVERVIEW OF SATELLITE CLOUD & RADIATION PRODUCTS FOR CRYSTAL-FACE

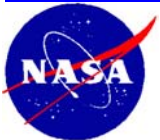
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**AS&M, Inc.
Hampton, VA**

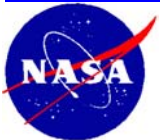
February 26, 2003



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OBJECTIVE

- **Provide Status Report of LaRC Cloud Products**
- **Note problem areas**
- **Future Processing**



Other LaRC CRYSTAL Satellite/Model Papers

Talks

- **Doelling -** **Cirrus/anvil statistics**
- **Smith -** **Surface Validations**

Posters

- **Nguyen -** **Web site, interactive resources, product availability**
- **Heck -** **Comparisons with model-generated cloud stats**
- **Duda -** **Comparisons with aircraft data**
- **Chepfer -** **Dual-angle, multi-satellite studies**
- **Wang -** **ARPS model forecasts/assimilation**



DATA

- Geostationary imager 4-km pixels *GOES-8, GOES-10*
 - 5 - 15 min resolution (1-km VIS available)
- MODIS 1-km pixels *Aqua (1330), Terra (1030)*
 - 2 overpass/day (night-day)
- AVHRR 1-km pixels *NOAA-15 (0730), NOAA-16 (1430)*
 - 2 overpass/day (night-day)
- VIRS 2-km pixels *TRMM* (variable overpass times)
- Input
 - 0.65 &/or 1.6 reflectances
 - 3.7, 10.8, and 12- μ m brightness temperatures
 - RUC T(z), q(z), O₃(z) each hour
 - Elevation, water %, IGBP type, CERES clear-sky albedos (10')



CLOUD MASK

Classify each imager pixel as cloud / clear / bad using multiple cascading thresholds, then each pixel is strong or weak

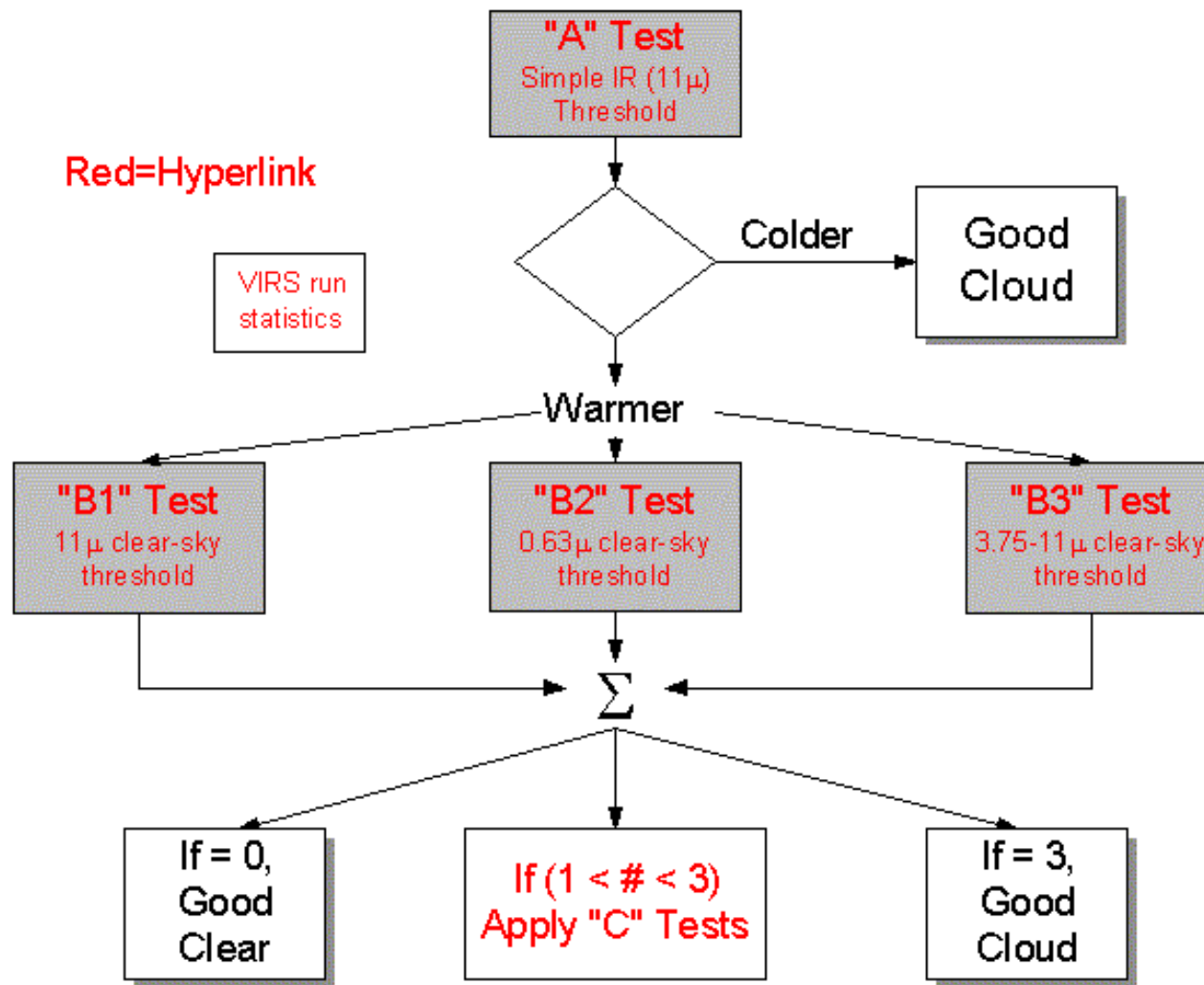
DAYTIME: SZA < 82°, 0.6, 1.6, 3.8, 11, 12 μm

NIGHTTIME: 3.8, 11, 12 μm



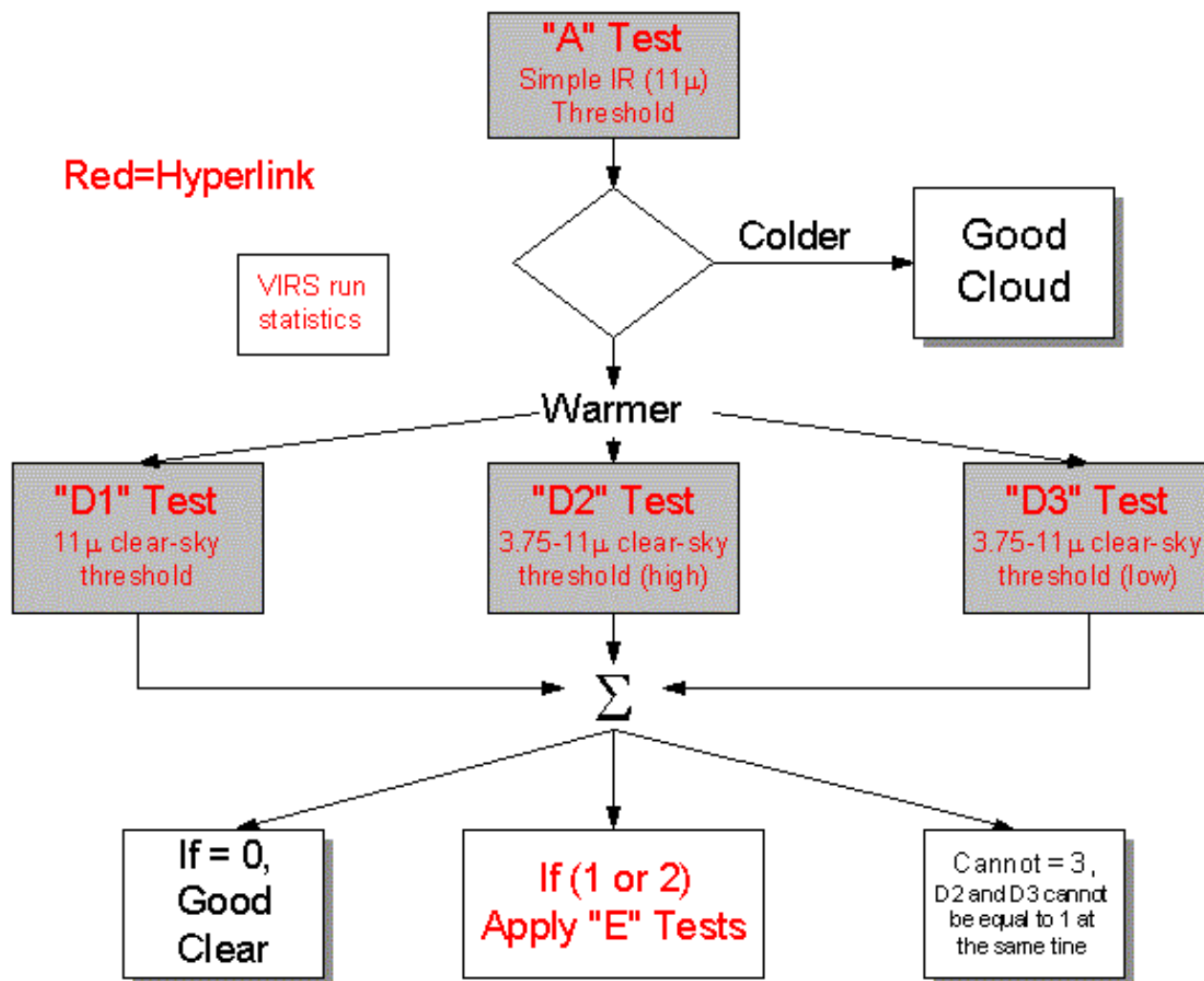
STANDARD DAYTIME MASK ALGORITHM

Top Level Daytime Flow Chart



STANDARD NIGHTTIME MASK ALGORITHM

Top Level Nighttime Flow Chart



CLOUD RETRIEVAL METHODOLOGY

- Compute ice & water solution, select most likely based on model fits, temperature, LBTM classification, 1.6- μm reflectance
water droplets: $r_e = 2 - 32 \mu\text{m}$
hexagonal column distributions: $D_e = 6 - 135 \mu\text{m}$
- No retrievals: reclassify as clear or status quo, 3-4%

RETRIEVAL METHODS

DAY: Visible Infrared Solar-Infrared Split-Window Technique (**VISST**)

see Minnis et al. (1995, 1998)

NIGHT: Solar-infrared Infrared Split-Window Technique (**SIST**)

see Minnis et al. (1995, 1998)

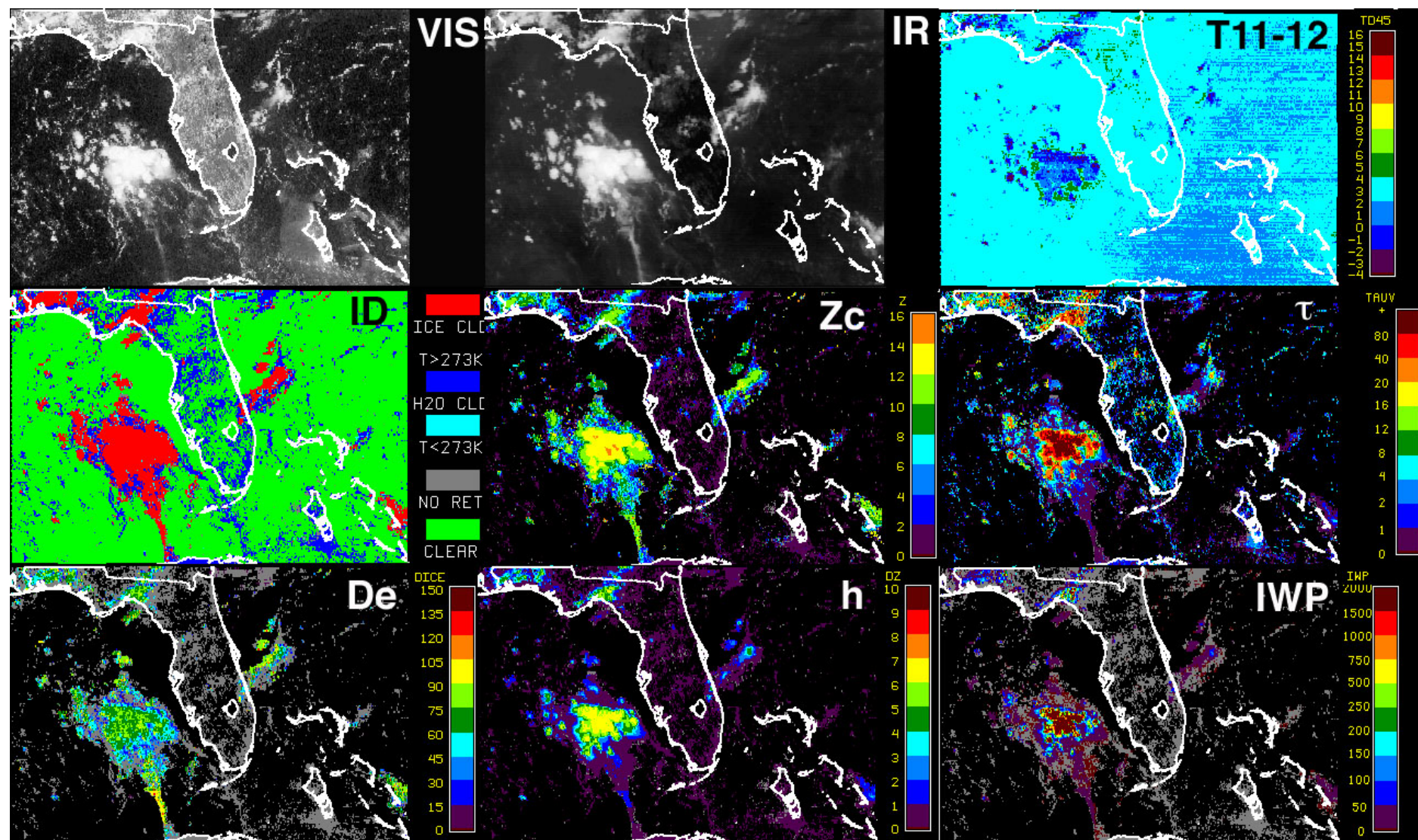


PIXEL-LEVEL CLOUD PROPERTIES

EFFECTIVE RADIATING TEMP	T_c
EFFECTIVE HEIGHT, PRESSURE	Z_c, p_c
TOP HEIGHT, PRESSURE	Z_t, p_t
THICKNESS	h
EMISSIVITY	ε
PHASE (water or ice; 1 or 2)	P
WATER DROPLET EFFECTIVE RADIUS	r_e
OPTICAL DEPTH	τ
LIQUID WATER PATH	LWP
ICE EFFECTIVE DIAMETER	D_e
ICE WATER PATH	IWP
BROADBAND ALBEDO, LONGWAVE FLUX	α, OLR



Cloud properties from GOES-8, 1615 UTC July 27, 2002



Some Cautions for Users

- Day-night differences (algorithm & spectral changes)
 - optical depth limitations at night (IR goes black)
 $\tau < 8$ not bad, $\tau > 8$ means optically thick
- Twilight ($82^\circ < \text{SZA} < 90^\circ$) & low sun ($\text{SZA} > 70^\circ$)
 - twilight: mask & retrievals questionable because VIS & 3.7 less useful
 - low sun: 3-D effects cause shadowing & bright cloud sides $\Rightarrow \tau$ & re , Ac
- Low-level cumulus clouds
 - daytime: partially filled pixels τ too low, re too high
 - nighttime: some low clouds missed
- Cloud overlap: not explicitly detected or corrected, affects semitransparent clouds
 - cirrus heights may be too low
 - cloud properties are mix of upper & lower cloud
 - not as bad at night because surface & low clouds temps close

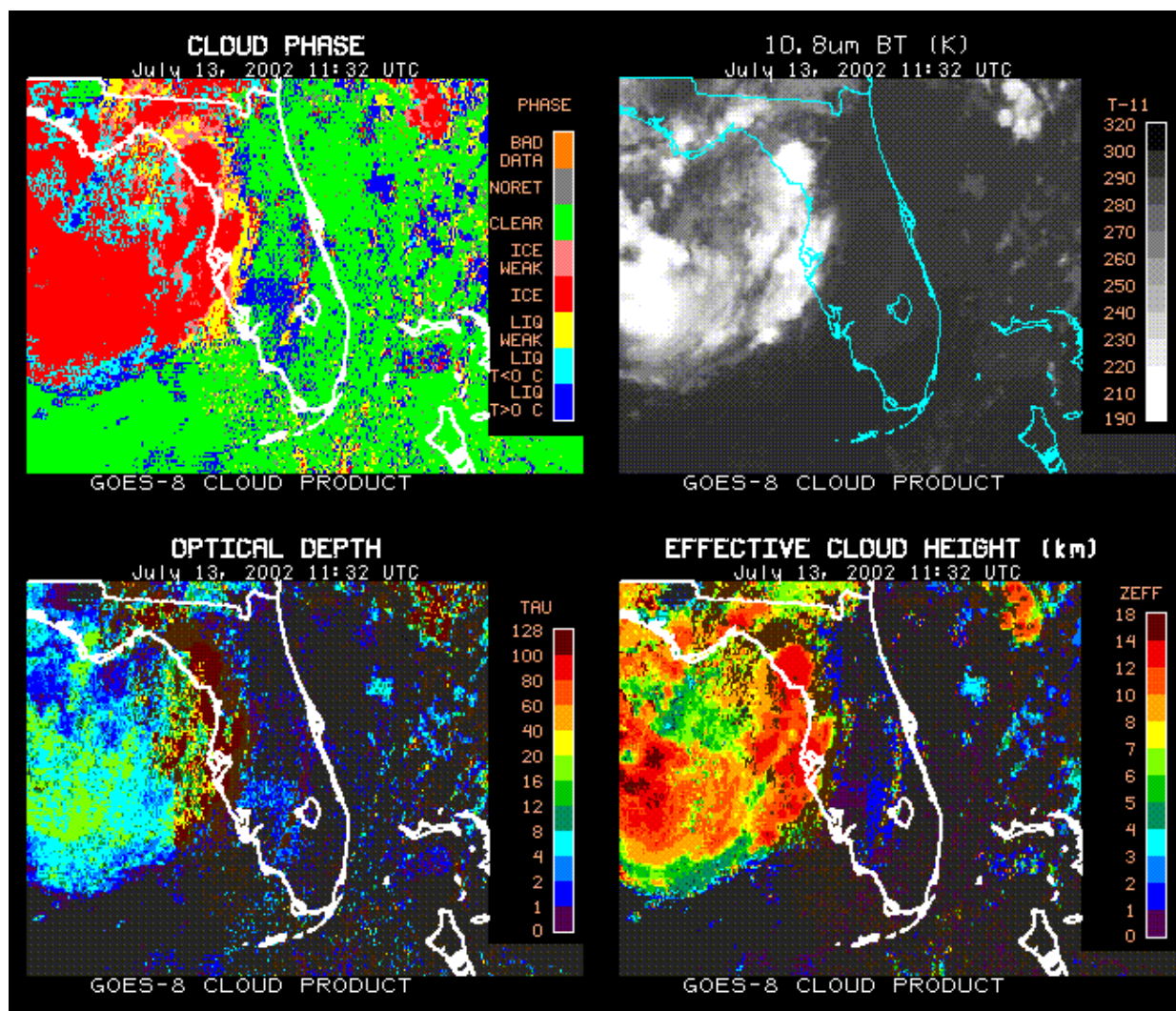


More Cautions

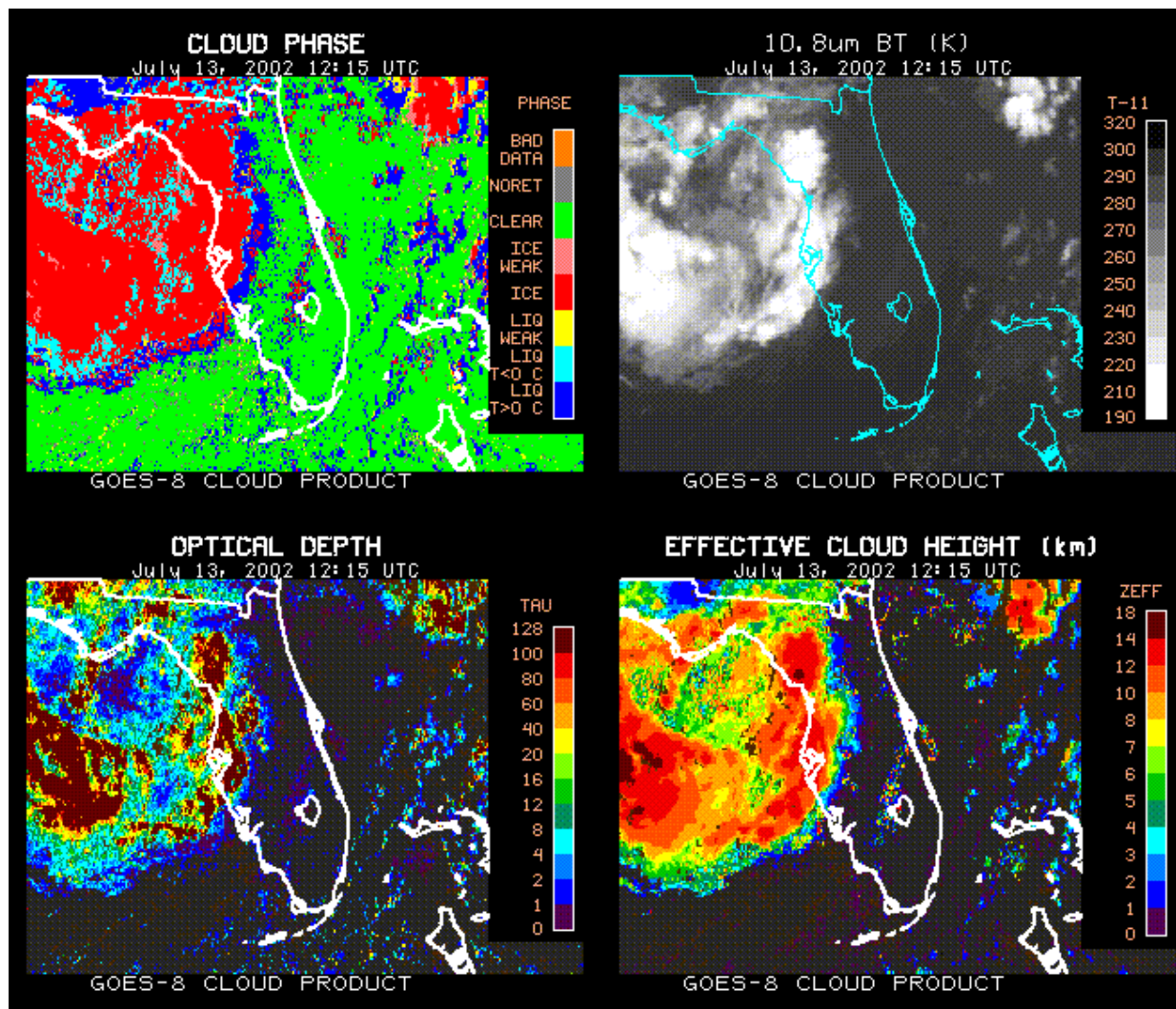
- **Cloud edges: partially filled cirrus may be interpreted as large re water**
- **Calibrations**
 - **GOES-8 VIS based on TRMM VIRS, MODIS is brighter:**
 $\tau(\text{MODIS}) > \tau(\text{GOES})$
- **Input**
 - **land clear-sky albedos based on VIRS/MODIS database**
GOES-8 VIS different filter function
 - **ocean albedos from an open ocean model**
bright shallow areas may be mistaken for clouds
 - **skin temperatures based on RUC surface air temperatures**
may under-/overestimate T_{skin} at given time & location
affects mask and retrieval of thin cirrus properties
 - **RUC has some burps**
contagious: cloud retrieval burps



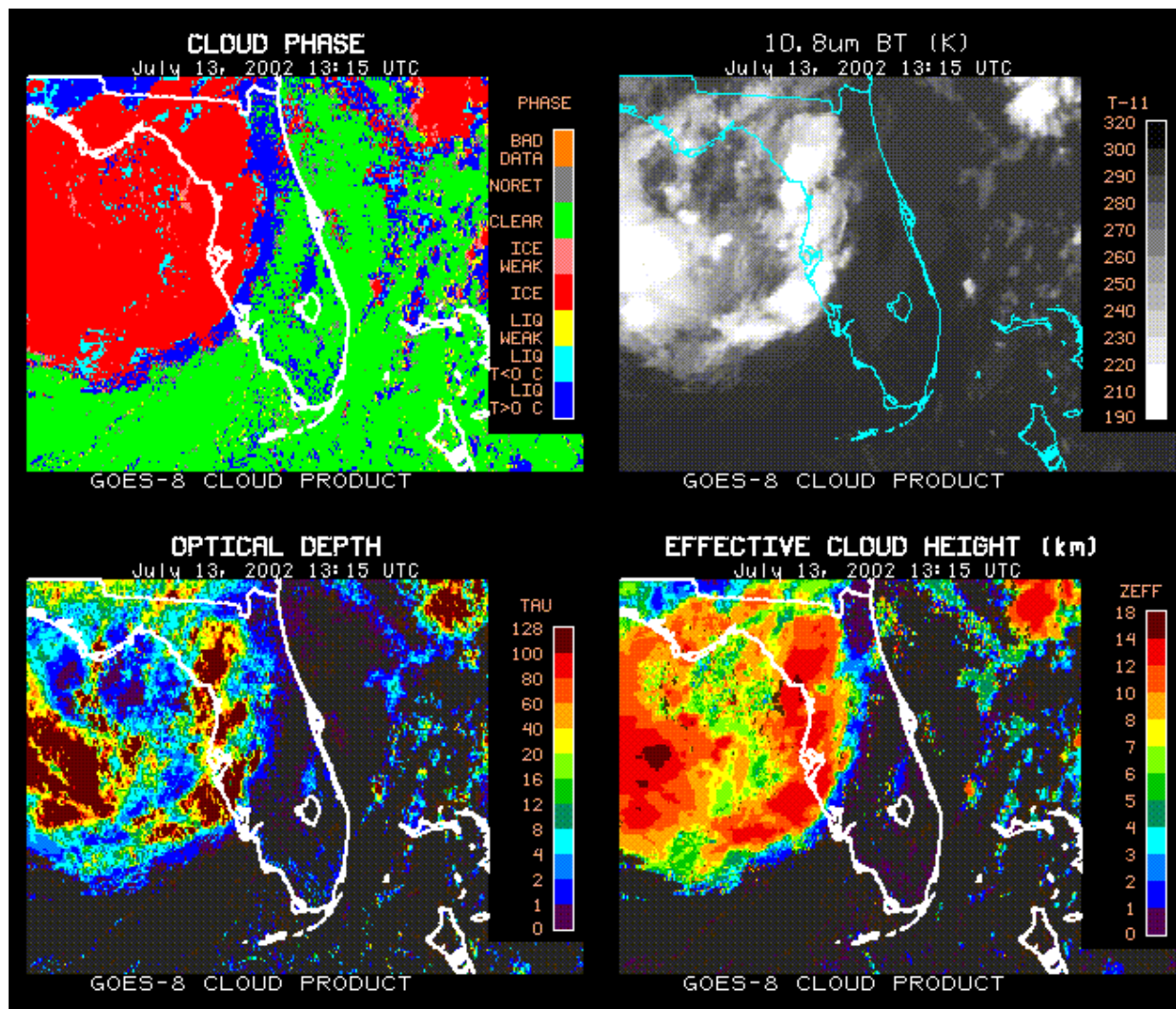
GOES-8 Cloud Products, 1132 UTC, July 13



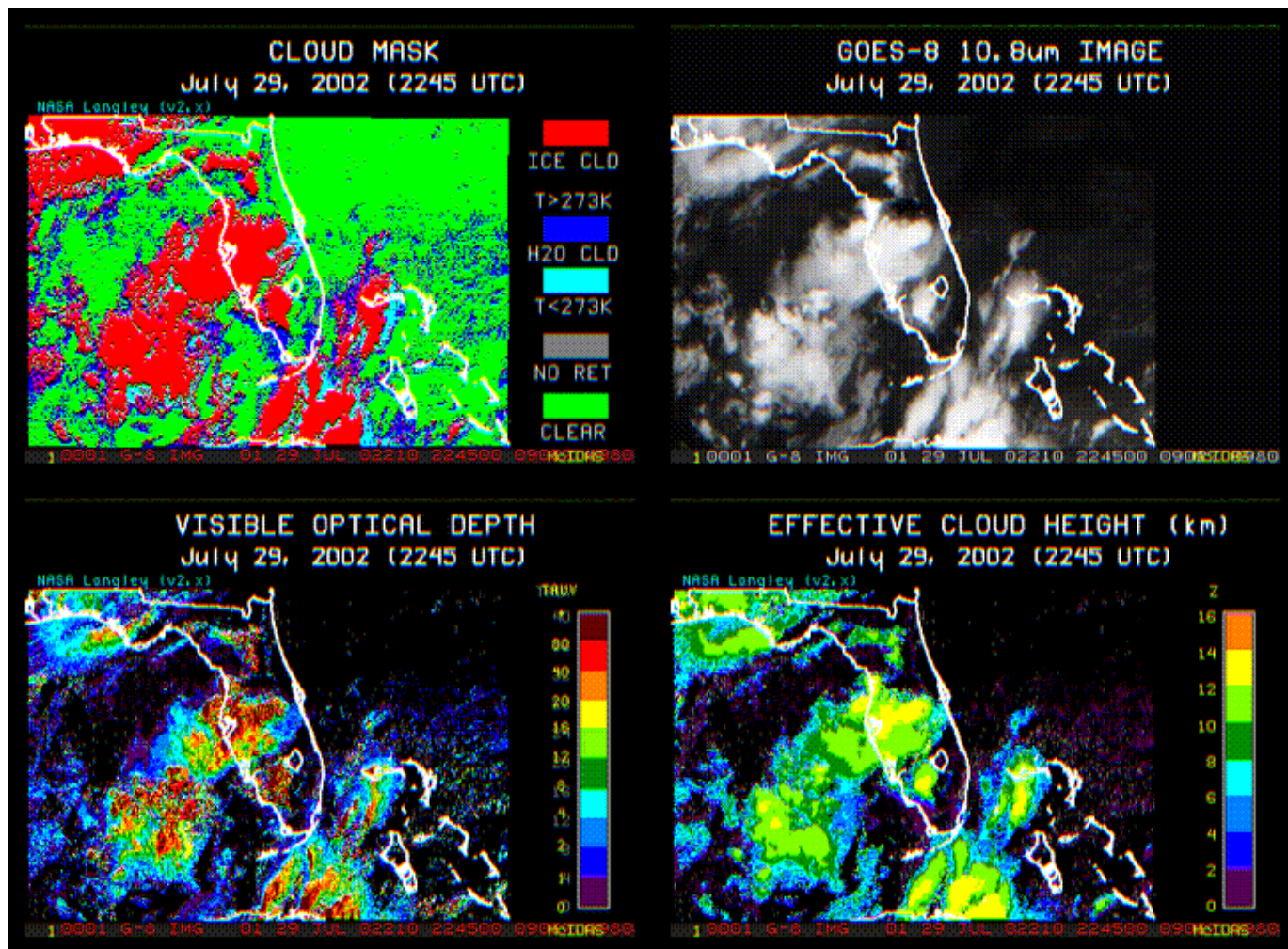
GOES-8 Cloud Products, 1215 UTC, July 13



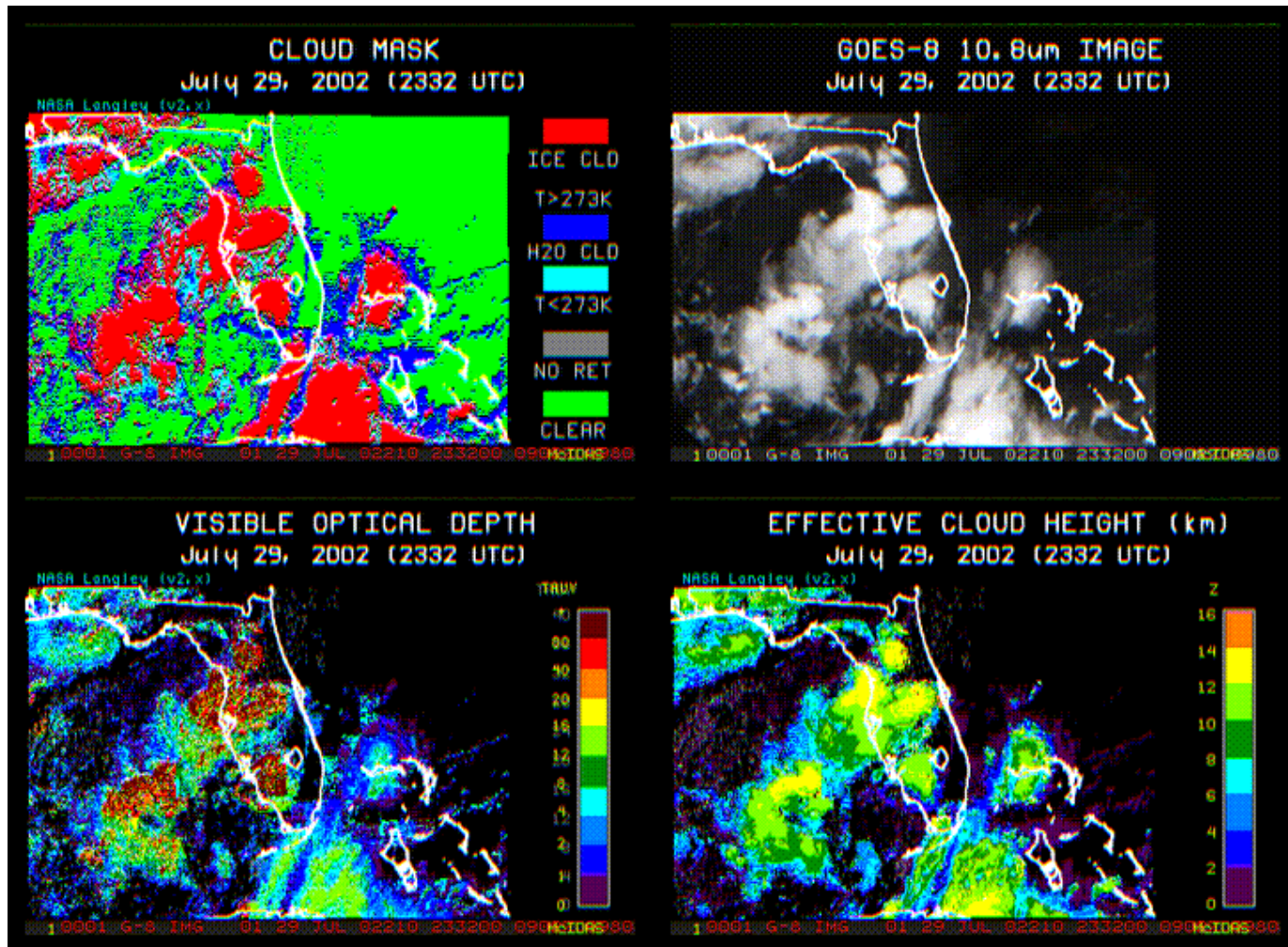
GOES-8 Cloud Products, 1315 UTC, July 13



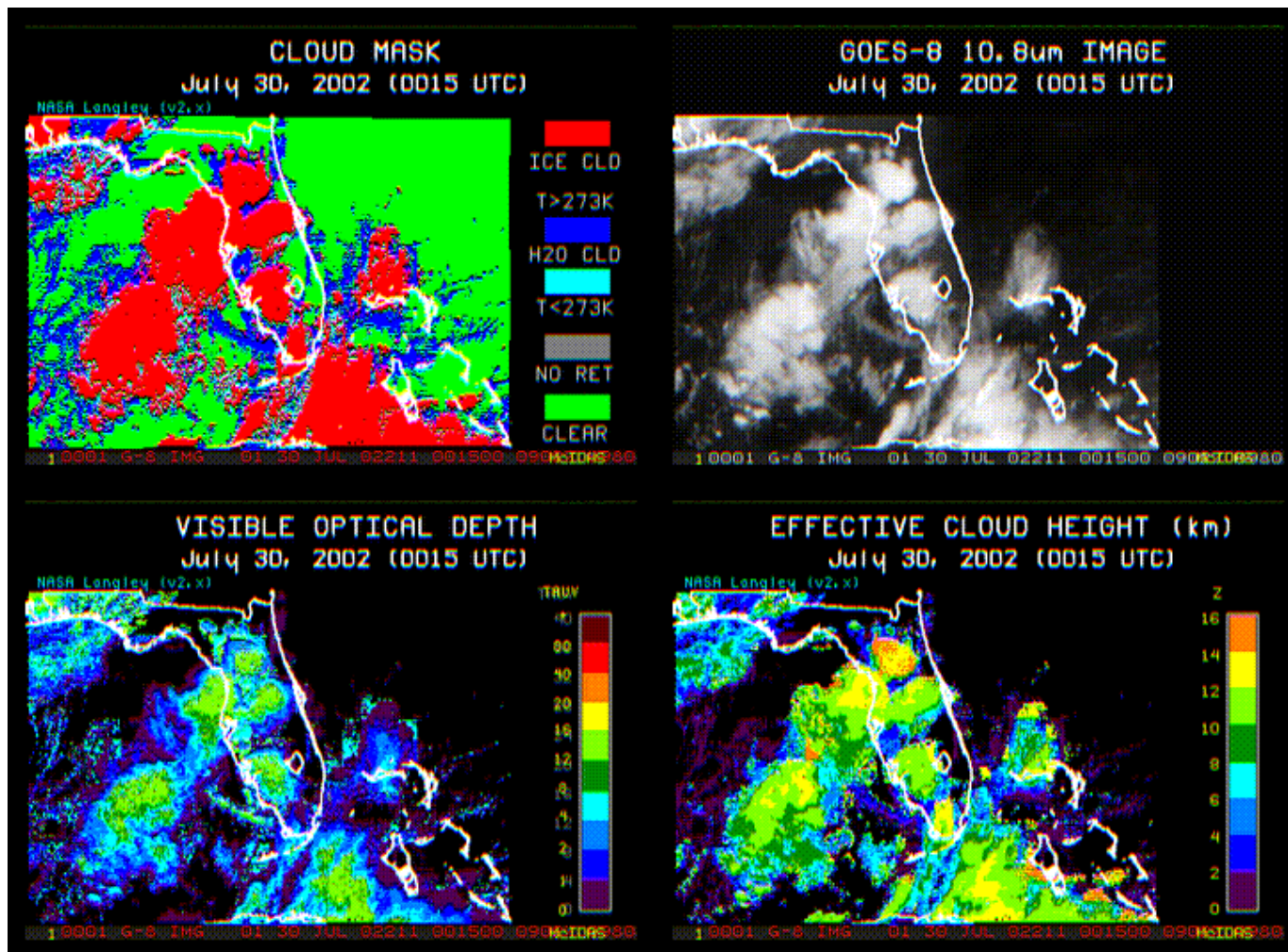
GOES-8 Cloud Products, 2245 UTC, July 29



GOES-8 Cloud Products, 2332 UTC, July 29



GOES-8 Cloud Products, 0015 UTC, July 30

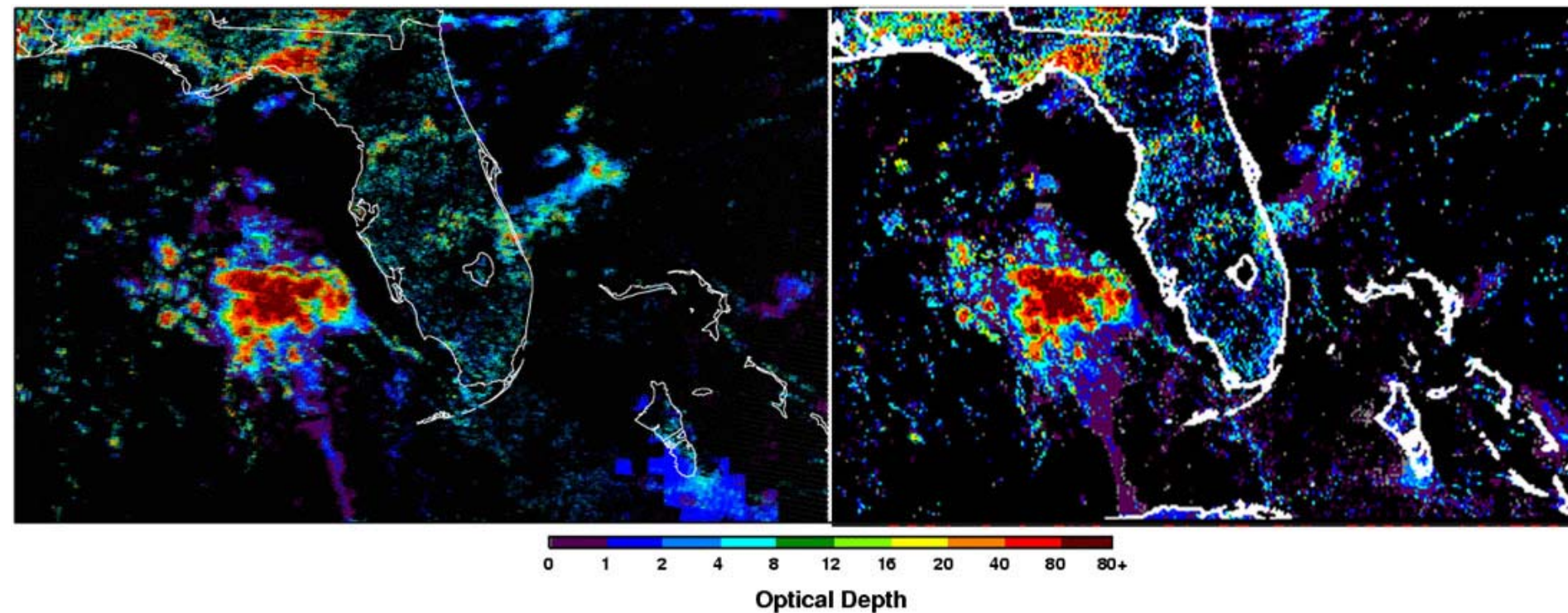


Comparison of Near-Simultaneous MODIS & GOES Cloud Retrievals

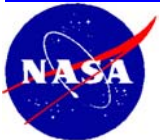
1604/1615 UTC 27 July 2002

MODIS

GOES-8

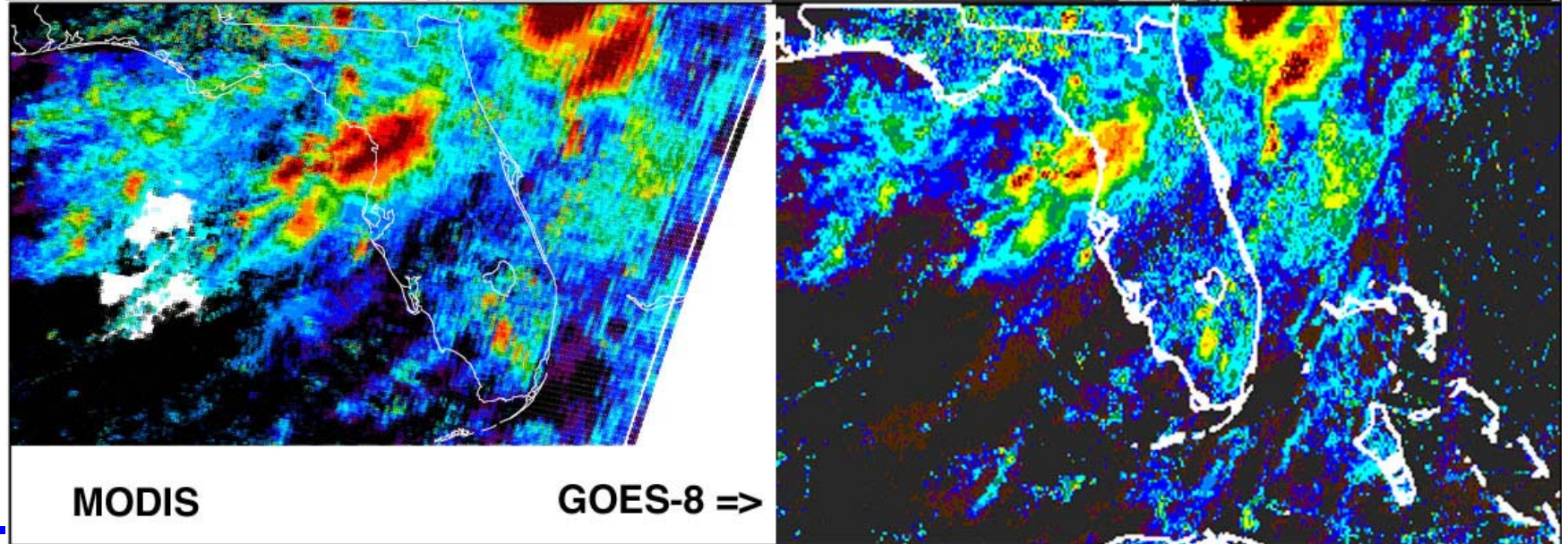
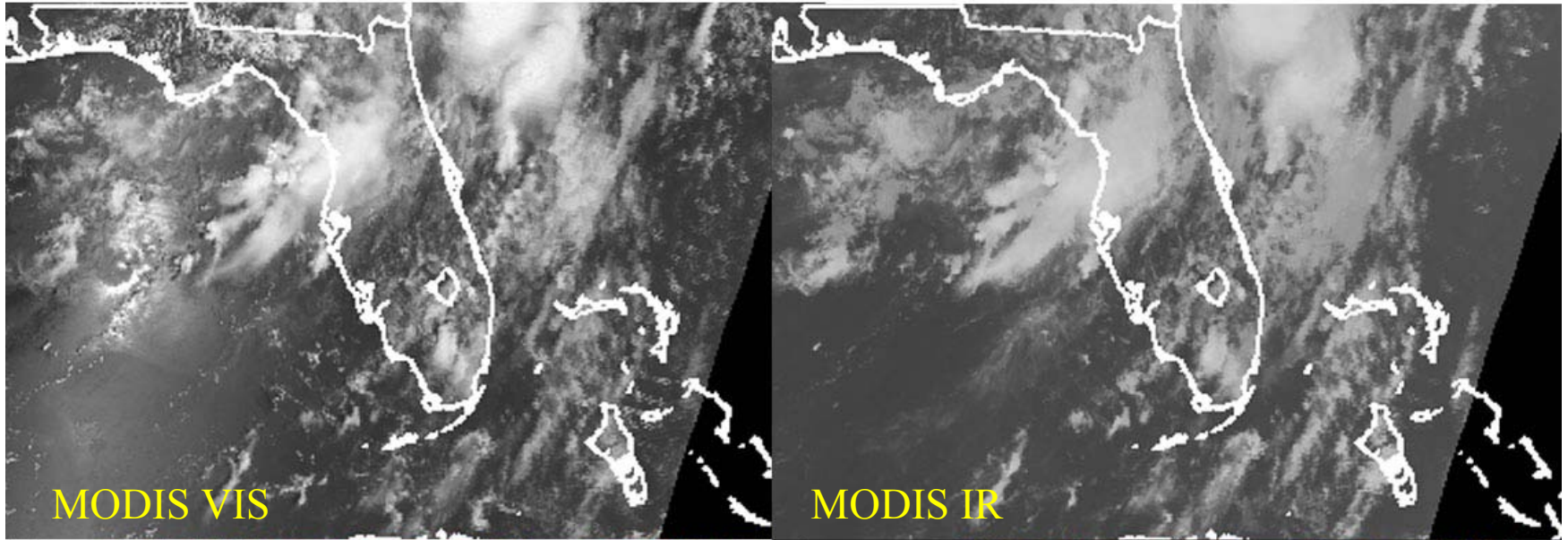


** Shallow-water effect on MODIS retrieval around Andros Island*



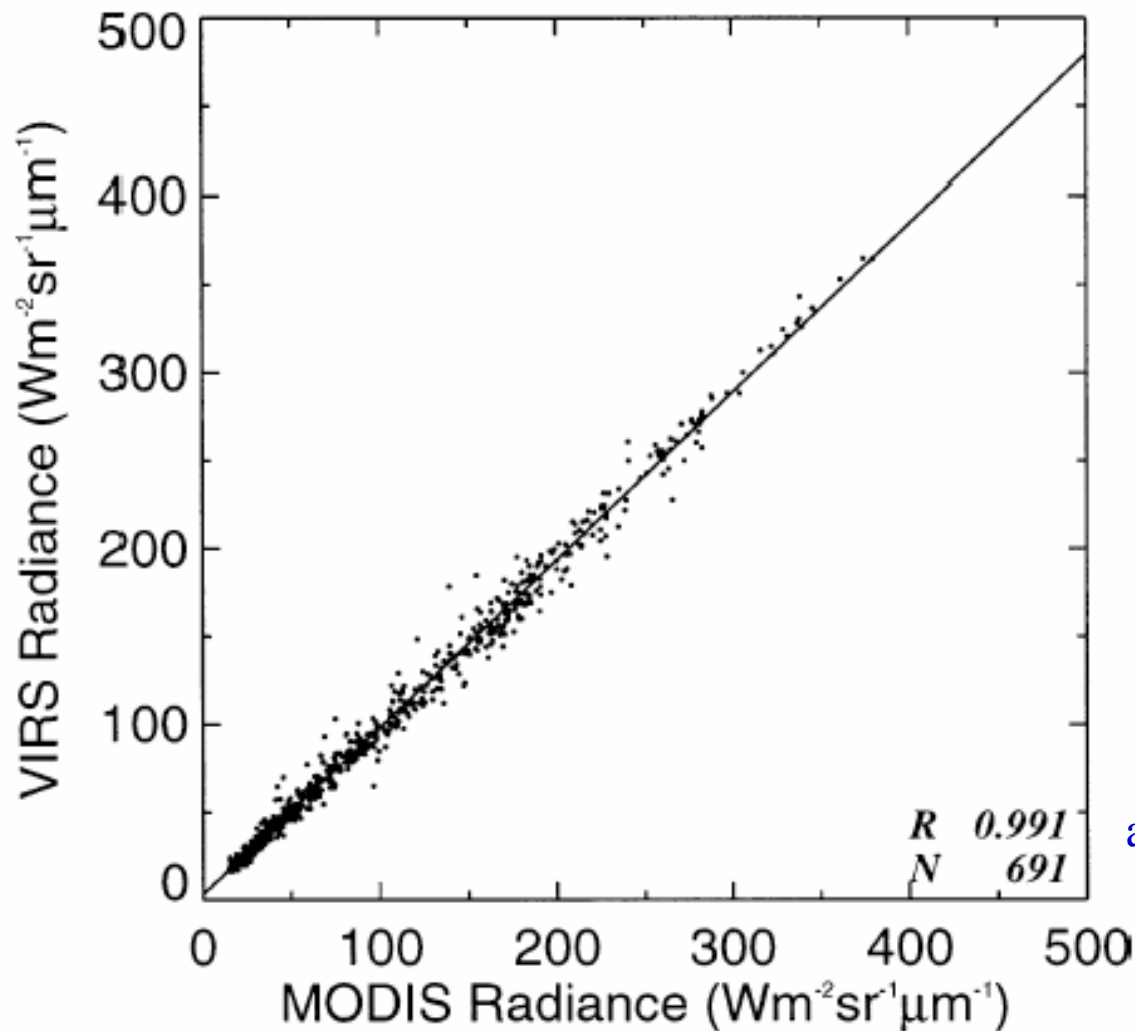
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COMPARISON OF MODIS & GOES-8 RETRIEVALS, 1630 UTC, 13 JULY 2002



0 1 2 4 8 12 16 20 40 80 80+

Optical Depth



Visible Channel Calibration

Terra MODIS vs VIRS

VIRS reflectance < MODIS
for brighter scenes

VIRS reflectance > MODIS
for dim scenes

Low end differences taken into
account with clear-sky reflectance
modeling, no high end correction

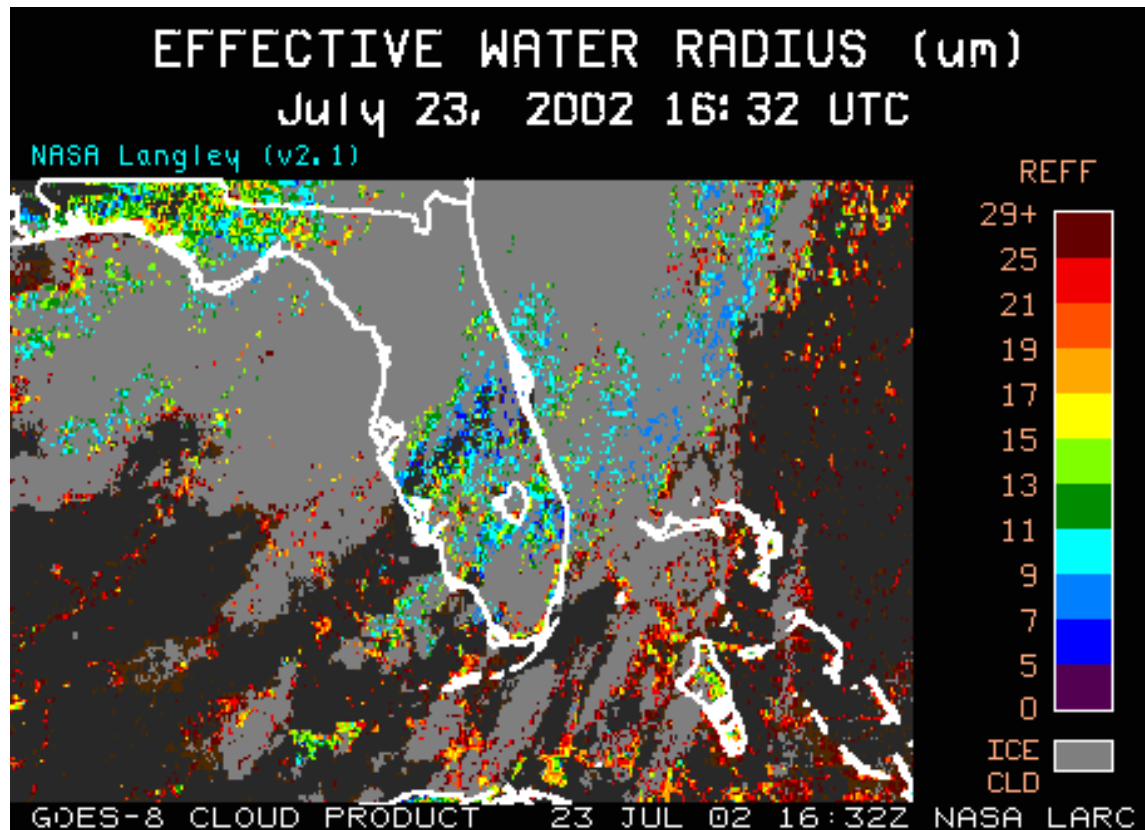
FIG. 11. Correlation of VIRS and MODIS ocean VIS data, Mar 2001.

Minnis et al., 2002, *J. Atmos. Oceanic Technol.*, **19**, 1233-1249.



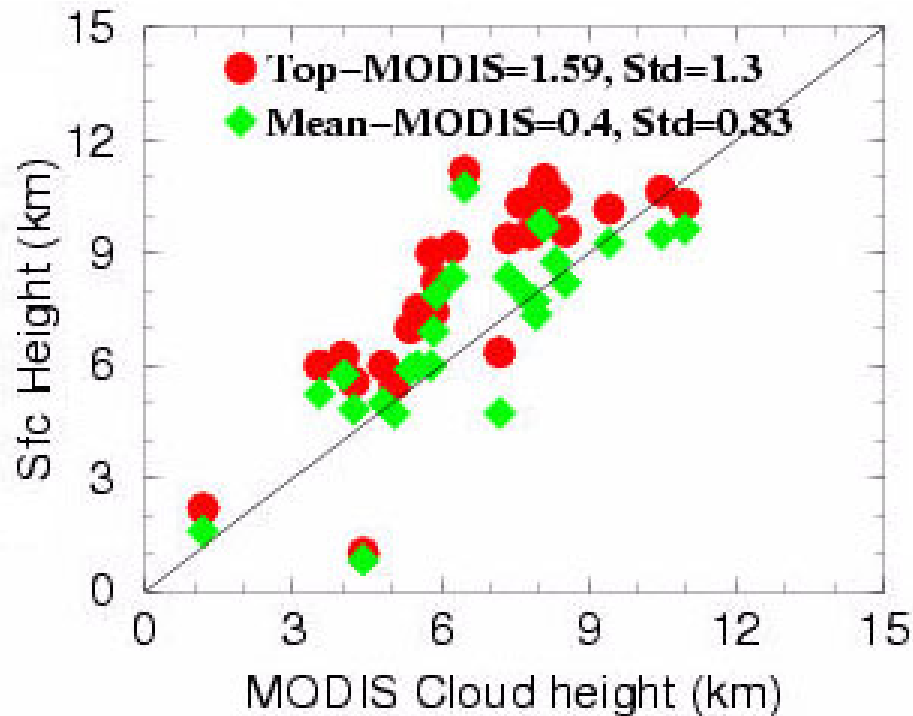
PARTIALLY CLOUD-FILLED PIXELS

- yields large re
- may misclassify cirrus as water cloud with large re

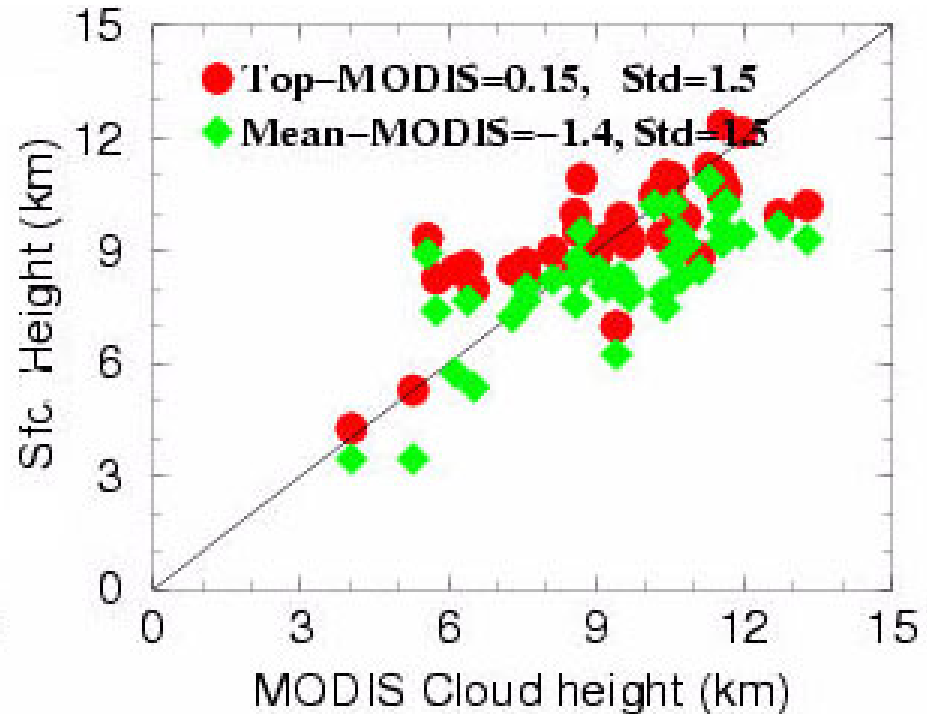


Validation of Thin ($\tau < 5$) Cloud Height over ARM SGP, MODIS 2001

Daytime



Nighttime



Nearly all thin cloud heights are within boundaries of cloud:

Clouds higher at night due to greater errors in skin temperature

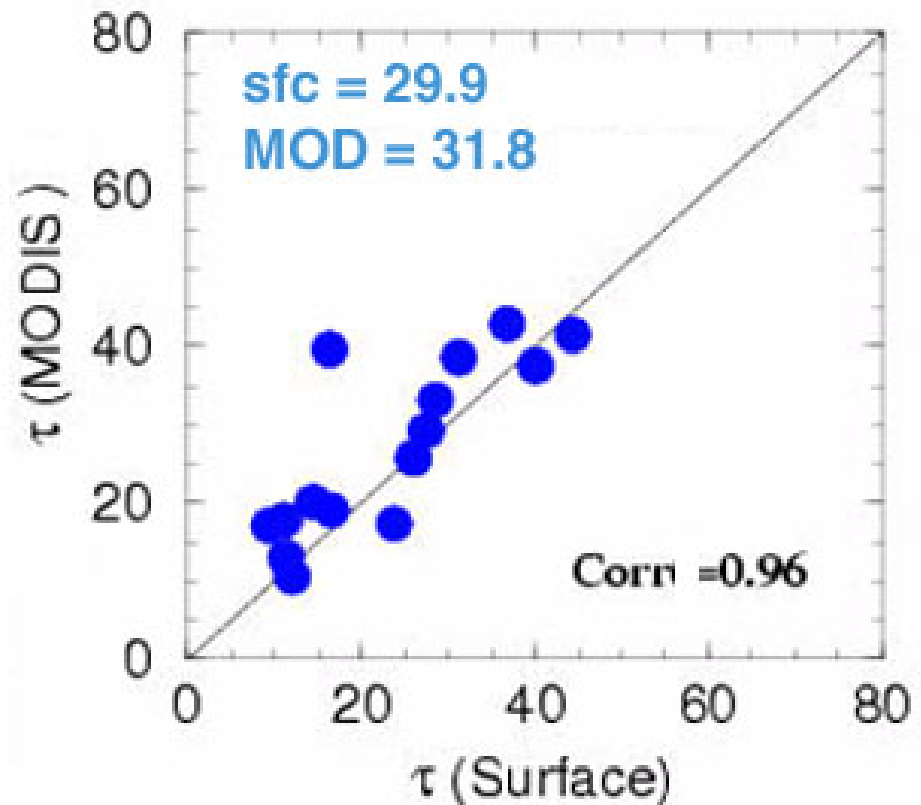
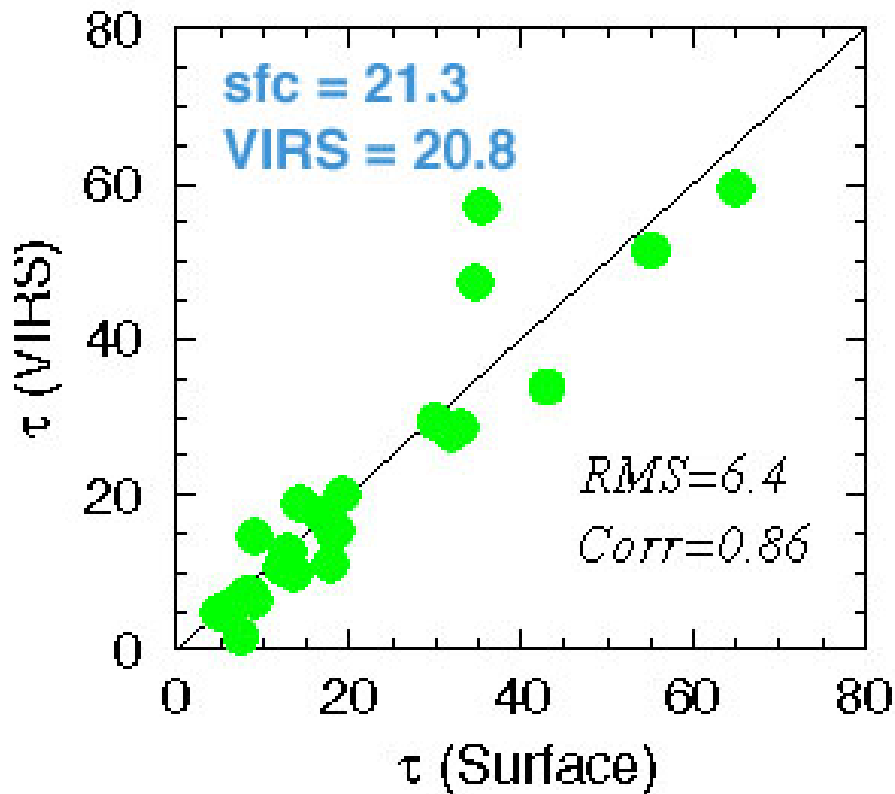
Boundary-layer cloud heights sometimes too high due to inversions

Implies cirrus optical depths are quite reasonable



Validation of CERES Cloud Optical Depth (Stratus)

ARM SGP, VIRS 1998; MODIS 2001



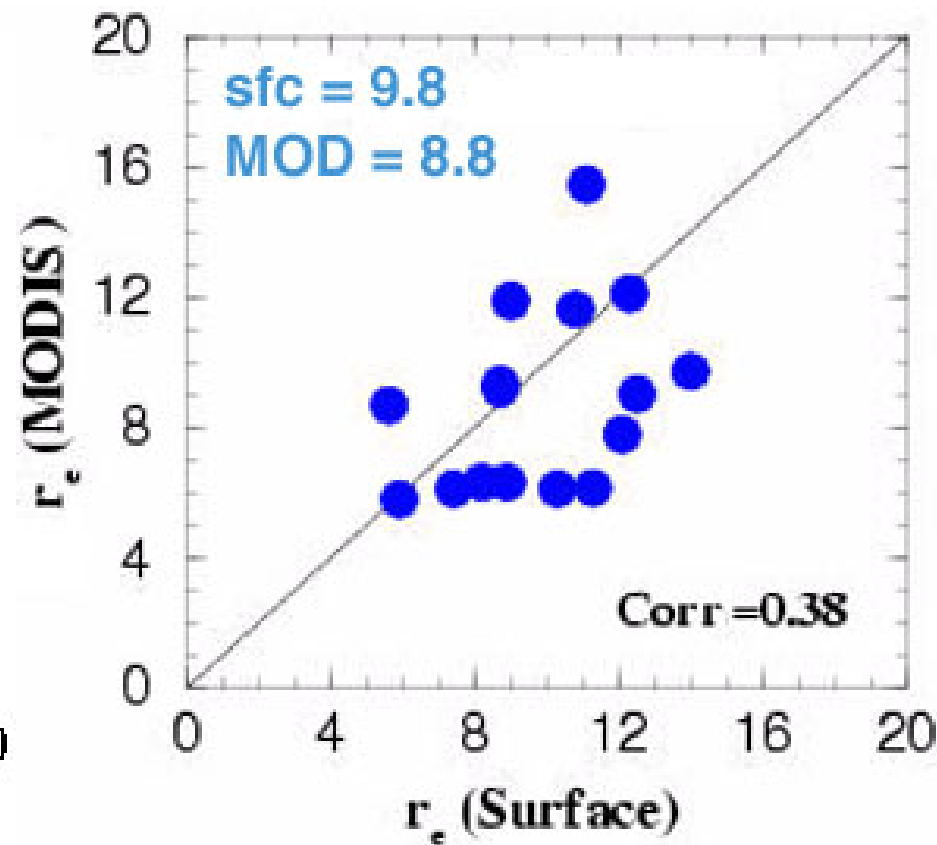
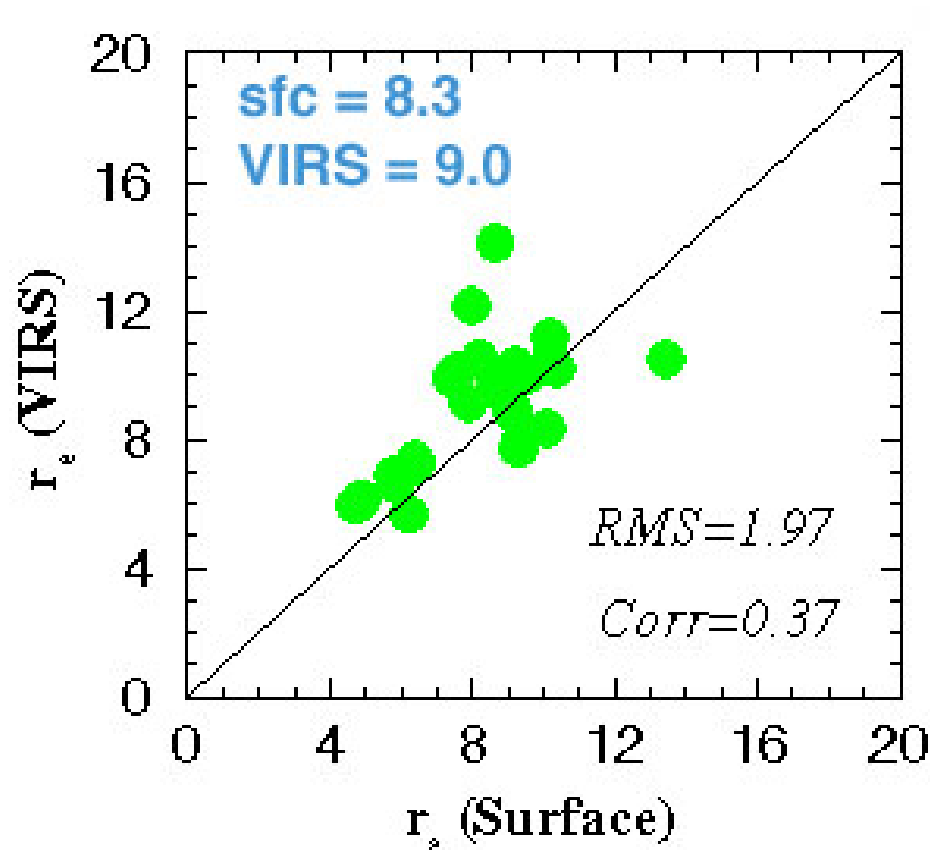
Excellent correspondence between CERES and surface-derived optical depths over ARM SGP site

For GOES-8, τ is comparable to VIRS comparison (*Dong et al. JAS 2002*)



Validation of CERES Cloud Droplet Size (Stratus)

ARM SGP, VIRS 1998; MODIS 2001



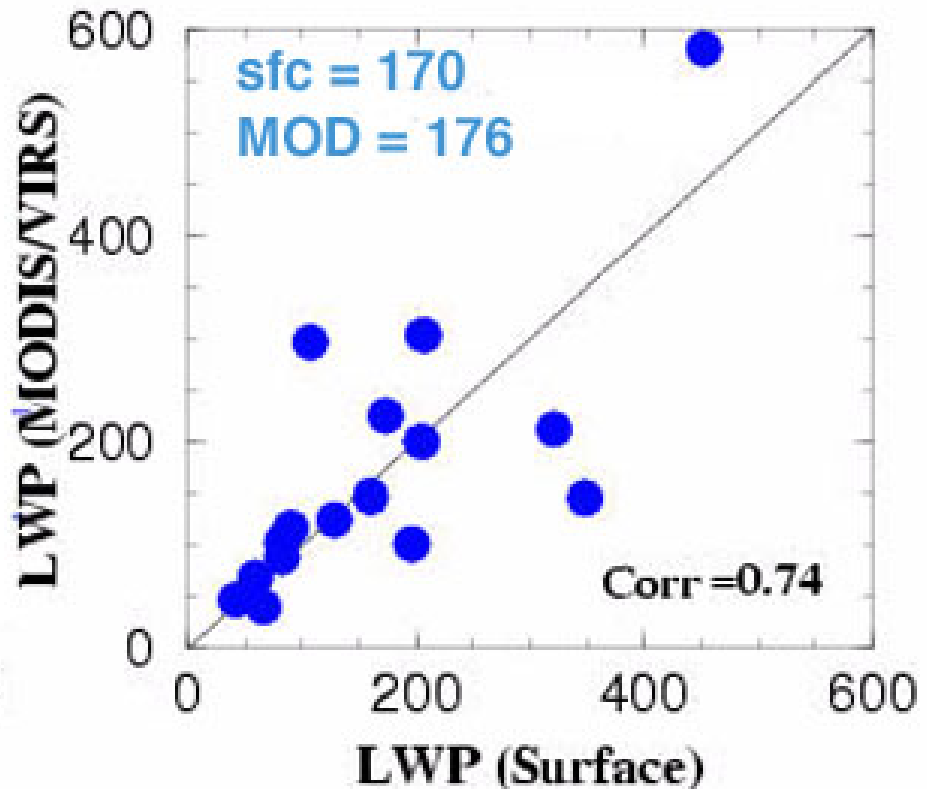
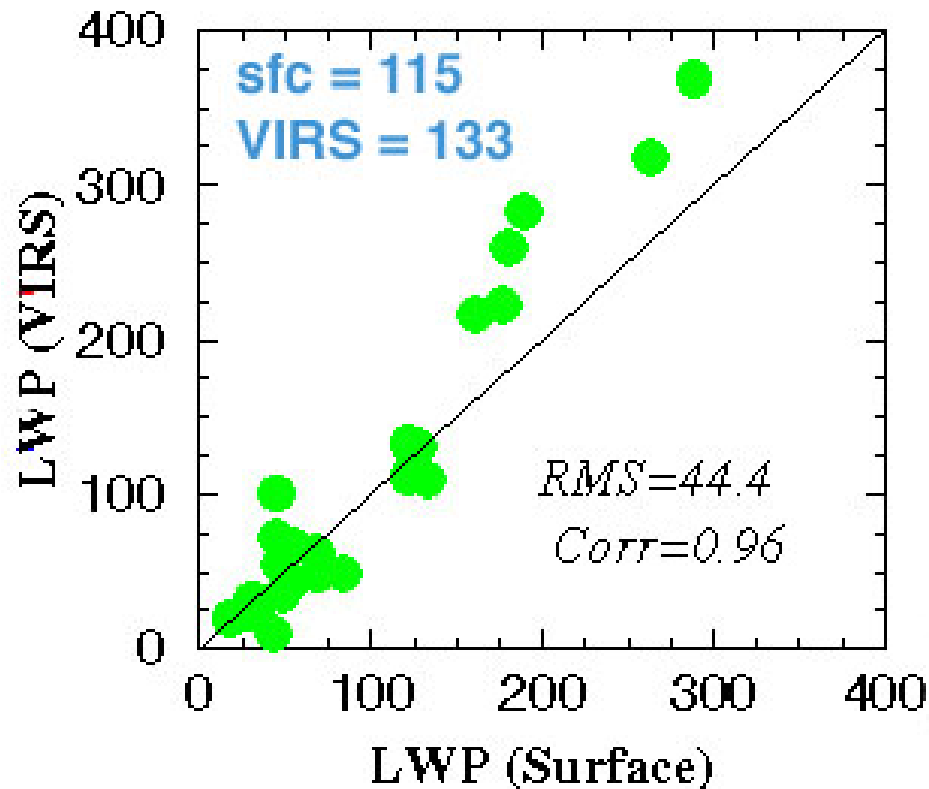
CERES average droplet sizes within $\pm 1 \mu m$ of surface-based values over ARM SGP site

For GOES-8, r_e is 14% larger than sfc value (*Dong et al. JAS 2002*)



Validation of CERES Cloud Liquid Water path (Stratus)

ARM SGP, VIRS 1998; MODIS 2001



CERES LWP slightly greater than surface-based values over ARM SGP site

For GOES-8, LWP 4% greater than sfc value (*Dong et al. JAS 2002*)



COMPARISON OF GOES-8 CLOUD AMOUNTS WITH TOTAL SKY IMAGER WESTERN GROUND SITE

ALL CLOUDS

	0	0	0	1	35	80-100
T	0	1	2	1	7	60-80
S	1	2	2	3	6	40-60
I	5	6	3	2	3	20-40
%	13	5	2	1	1	0-20
	0-20	20-40	40-60	60-80	80-100	
	VISST 10km CLDAMT (%)					

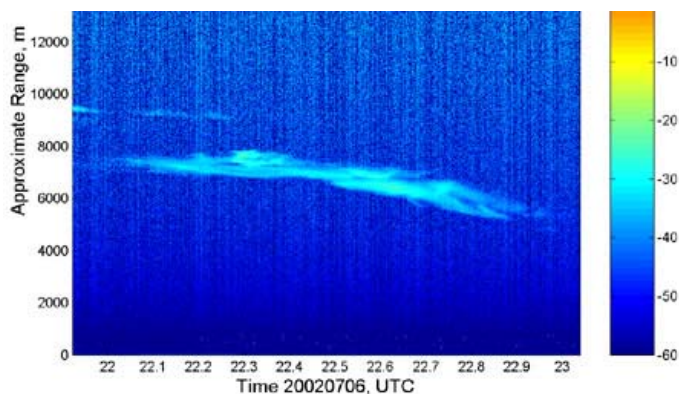
**GOES bias due primarily to TSI
missing thin cirrus, also scattered cu**

N = 971
Avg_tsi = 56.827
Avg_visst = 65.461
Bias = 8.634
RMS = 23.403

OPTICALLY THIN CLOUDS

	0	0	0	1	7	80-100
T	0	0	1	1	23	60-80
S	0	0	0	8	21	40-60
I	2	3	6	3	13	20-40
%	1	5	0	2	1	0-20
	0-20	20-40	40-60	60-80	80-100	
	VISST 10 km CLDAMT tau < 2; Zeff > 6km					

N = 86
Avg_tsi = 50.897
Avg_visst = 79.617
Bias = 28.721
RMS = 35.592



SUMMARY

- GOES-8 results are in pretty good shape and should be useful
- Beware of the caveats!
- Reprocessing

GOES-8: partial cloudiness (1-km VIS + 4-km IR)

upgrade background reflectance & skin temperatures

try ID of overlapping thin clouds

try improvement of twilight cases

test increasing τ limit at night

MODIS: upgrade background reflectance & skin temperatures

examine calibration for consistency with GOES

Need access to Aqua data!

AVHRR: run N-15 & 16 cases

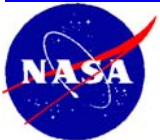
- Continue validation with CRYSTAL data collaboratively



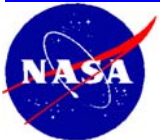
DATA ACCESS

- Data viewing and access: [**http://angler.larc.nasa.gov/crystal/**](http://angler.larc.nasa.gov/crystal/)

Check out Louis Nguyen poster for examples of tools, images, data links, etc.



Thanks to J. Mather & PARSL gang for the TSI & radar data



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